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# The influence of teachers' statistics knowledge on the academic performance of high school students in math lessons

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## ABSTRACT

Statistics and probability is one branch of mathematics with numerous conceivable outcomes and problem-solving circumstances that require a basic problem-solving aptitude. The purpose of this study is to determine the need for high school mathematics teachers to teach statistics and probability, which would serve as a basis for improving the level of teaching statistics and mathematics in general. A descriptive research method was applied in this study, and a two-part survey was employed as the primary method of data collection. A total of 34 secondary school mathematics teachers from 23 private and public secondary schools in Kazakhstan acted as respondents to answer a specially designed questionnaire. The mean value, percentage of frequency, standard deviations, correlation, regression, percentage of correct answers and average percentage scores were used. Based on the responses, the respondents have a low level of knowledge regarding the content of statistics, but their students have satisfactory results in statistics and mathematics. The results of this study will give scientists an idea of how to improve the level of training of mathematics teachers. In addition, since higher educational institutions are engaged in the training of mathematics teachers, they need to think about the methodology of teaching statistics, as well as teacher training institutes, to adapt courses and seminars for teachers.

**Contribution/Originality:** This study contributes vital insights into the correlation between teachers' statistics proficiency and high school students' math performance, informing teaching practices and educational policies. It also addresses the specialized domain of statistics within the high school math curriculum and adds a distinctive touch, presenting a unique perspective on how teachers' expertise impacts student success.

## 1. INTRODUCTION

The development of modern society and education require new approaches to the establishment of academic processes and new qualities in the portrait of schoolchildren, who must be prepared and diversified into the world of adults, capable of independently solving many issues, finding optimal situations, generating ideas and proposing them. One of the steps taken to modernize the content of mathematical education was the inclusion of statistics in

secondary school programs. To date, Kazakhstan has undergone several educational reforms. The main reasons for this are the desire to study in accordance with international standards required by society and the strengthening of the applied orientation of mathematics.

The most challenging subject to teach and comprehend has traditionally been considered to be mathematics. Math student achievement is regularly below average when compared to other curricular disciplines. Various strategies have been used to address this problem, from the national level to the school level. Mathematics teaching staff continually develop new strategies and put them into practice to improve their pupils' academic achievement. Students should learn a variety of mathematical specialties due to the development of modern society, which requires new approaches to the organization of the educational process and develop new qualities in schoolchildren to prepare them for adulthood. The opportunity to familiarize students with statistics and probability opens up great opportunities for the application of mathematics in solving applied problems because statistics are related to students' proximity to life situations that they face every day and which they will inevitably face in the future. At the end of high school, students take an exam in mathematics and, upon admission to university, take a national state test in four main subjects and one elective subject. Weather forecasting, standard of living, sports, games and entertainment, business vulnerability analysis and game theory, environmental legislation, product quality, protection tactics, healthcare solutions, contingency planning and census data are just some of the examples of content found in university entrance exams. Therefore, knowledge of statistics and probability is important for high school students, and students' knowledge is directly related to teachers. For a more detailed understanding, since 1999, elements of probability theory and mathematical statistics have been included in school mathematics programs. In the mandatory secondary education curriculum of the Republic of Kazakhstan, as ratified in 2002 and as it presently stands, the foundational mathematics content includes the study of probability theory and mathematics statistics. Statistics and probability was introduced in schools in Kazakhstan relatively recently. This raises many questions, some of which we try to answer in this article. Since statistics is taught as part of mathematics, the curriculum of Kazakhstan shows irregularity among its topics and the non-connection of tasks with life. The problem of boring questions is considered a disadvantage of the curriculum in many Asian countries. For example, Chi (2022) suggested that Vietnamese textbooks should consider augmenting required probability and statistics information, which has numerous applications to real life situations. Increasing the quantity of actual circumstances and employing an inductive method to probability and statistics material should be prioritized.

Since statistics is one of the most important lessons in modern society, it is necessary to pay special attention to the methodology of teaching it. Students' statistical literacy would increase if statistics was taught with new methodology in order to enable them to work with data found in all fields of science.

Therefore, this work seeks to answer the following questions:

1. Why is teaching statistics in mathematics important for high school students?
2. What kind of specific features and characteristics can we nurture in students through teaching statistics?
3. How much of an impact does a teacher's level of knowledge have on students' performance in statistics/math?
4. How can we improve the level of statistics knowledge by working on teaching issues?

### *1.1. Education and Issues in Statistics*

Recent improvements in technology have advanced so much that almost each sphere of business relies on statistical research. As a consequence, students' interest in statistics courses is growing, and there is a need in the marketplace for specialists with solid skills in applied fact analysis who can make trustworthy decisions in the face of ambiguity. Statistics nowadays needs well-developed practical information analyzing abilities, which are best

procured as a result of serious work with real-world case studies, frameworks, and programs. The goal is to conduct this learning in an environment where errors can be made and outcomes can be assessed (Arsham, 2020).

In an age full of information, statistics should be provided at a basic level so that people can understand the information. One of the most demanded professions is specialists in data science. Students must become acquainted with data science in order to be better equipped for future jobs. Data science is the study of identifying usable information from data in various ways. Students may accomplish this at a basic level, concentrating on exploratory data analysis using interactive reports (Kadijevich, 2019). It demonstrates the importance of continuing to improve statistics education. There are many studies that show that improving the ability of teachers to organize classes, improve their knowledge in accordance with modern requirements, and familiarize themselves with new methodologies has a positive effect on students. Wijaya and Doorman (2021) contribute to the establishment of a local instruction theory for the teaching and learning of probability via game-based learning. The findings indicate that using games and related tools can help students enhance their grasp of probability. Pupils' comprehension of probability develops gradually as they progress through four stages of modeling: situational, referential, general and formal levels. Pupils obtain a knowledge of probability concepts and go from the first level to higher levels of modeling with the use of both game-based and mathematical tools. Additionally, this study demonstrates that game-playing terms and interactions might boost students' understanding of mathematical concepts (Wijaya & Doorman, 2021). According to Mendez (2022), problem-based learning as a method of teaching mathematics can be utilized by teachers as a tool to increase students' learning of mathematical statistics. Teachers' warm-up activities, motivation, and lessons have an impact on students' success level in statistics and probability (Moroni & Brun, 2019).

Several strategies and tools have been identified as effective for teaching statistics. A study by García-Pérez, Flores-Alfaro, and Gómez-Albores (2019) found that problem-based learning improved students' understanding of statistical concepts, data analysis skills, and critical thinking abilities. Similarly, Ang, Tan, and Tee (2021) reported that problem-based learning enhanced students' motivation and engagement in statistics.

Visualizations, such as graphs, charts, and diagrams, have also been identified as effective for teaching statistics. Bakker, de Vries, and van den Heuvel-Panhuizen (2020) found that using visualizations improved students' understanding of statistical concepts and reasoning skills. Ang et al. (2021) reported that using visualizations in teaching statistics improved students' engagement and interest in the subject.

The most crucial aspect of education is a well-designed curriculum and textbooks. Due to its relevance, application, and value in research, current studies highlight the need to increase pedagogical content knowledge and abilities among teachers of statistics and probability. To consolidate and expand understanding of probability and statistics, Vietnamese textbooks should make use of project work, simulation, and technology (Chi, 2022). Deductive methods are frequently used to compel information acceptance among Vietnamese pupils. Vietnamese pupils will have to learn to use logical methods. German textbooks, on the other hand, maintain that mathematical knowledge must be adjusted to real life in order to rebuild its true essence, because mathematics is derived from real life situations (Chi, 2022). As a result, knowledge of probability and statistics in German textbooks was provided inductively through numerous concrete scenarios. Life-related tasks are engaging and entertaining for pupils.

Programs should be updated for each age level and regularly revised to improve learning effectiveness. However, owing to expense, license requirements, and other issues, not all teachers or students can use statistical software (Jaudinez, 2019). As there is no such thing as a flawless curriculum, teaching mathematics has never been simple for teachers given the absence of instructional tools as well as training since its inception in 2016 (Jaudinez, 2019). Seminars for teachers on mathematics, mathematical instruments for teaching, technology, results-based activities, and shortcomings in suggested or chosen ways to teach complicated topics have assisted school teachers in carrying out the intended curriculum efficiently (Jaudinez, 2019). Although students' difficulties with learning statistics include self-related problems, teacher-related problems, and material-related problems, instructors'

problems with instructional time allocation include problems with students and teachers as well as problems with the curriculum (Moroni & Brun, 2019). To address difficulties with knowledge overload and to put greater emphasis on acquiring essential ideas, teachers should think about changing the rules for the statistical curriculum. Strengthening the content and pedagogical competence of statisticians and probability teachers can help to improve statistical literacy. To address the issue of insufficient learning resources, schools should collaborate with governmental and non-governmental organizations. Further study on the influence of teachers' time allocated to statistical achievement levels is required (Moroni & Brun, 2019).

The educational objective is stated in practically every subject taught as part of the school curriculum, and it is connected to the idea that education is crucial for the development of children's skills. For instance, to solve mathematical problems, it is not enough just to learn the rules, you also need attentiveness, perseverance, and accuracy. So, while you are thinking about the task, you are using other skills in parallel. The instructional activities used in the study by Funny, Ghofur, Oktiningrum, and Nuraini (2019) were successful in revealing students' reflective thinking abilities. Nonetheless, pupils must be encouraged to reflect spontaneously on their learning experience. This study examines how students actively participate in reflective thinking in statistics lessons by using project-based learning based on design research. As a result, lecturers and learning activities continue to play an essential role in directing students toward improved reflective thinking skills (Funny et al., 2019). In order to answer statistical and probability questions, you must be able to examine facts and ideas, generalize, explain, offer reasons, speculate, and reach a conclusion. All of these things are possible if you can think logically. Making judgments and solving statistics and probability challenges require logical reasoning. The capacity to reason rationally includes high-level mathematical abilities that pupils have not acquired. This is due to the fact that pupils are not accustomed to doing so during the learning process. Thus, teachers can help develop students' capacity to think logically through a range of learning methodologies, and eventually they will grow acclimated to working on statistical and probability issues (Puspitasari, Afriansyah, Nuraeni, Madio, & Margana, 2019). Logical mathematical thinking abilities need to be taught in a creative way that offers pupils the chance to use and develop skills in order to overcome challenges in completing assignments.

Statistics is often included in secondary curriculum as a few lessons as part of mathematics and is mostly taught in a procedural manner. There appears to be a gap between math teachers' education and the teaching requirements placed on them. Studying statistics from a mathematical standpoint does not qualify one to adequately teach the topic. Seminars and teaching courses for statistics teachers should be developed, as the efficiency of training programs has been demonstrated in research.

According to the results of a workshop held in Argentina for 500 math instructors, statistics appear to be important in the training of pupils in both their personal and social lives (Fernández et al., 2020). Teachers regarded the supply of new resources, such as exercises focusing on statistical reasoning and real data rather than computations, as acceptable and practicable to employ in the classroom for teaching statistics in secondary school and had a proactive attitude toward using them. Based on feedback, it has been shown that seminars have helped teachers to teach statistics.

Statistical literacy based on research interprets, evaluates and transfers statistical data (Gal, 2002). As such, it is closely related to statistical education. Additionally, the value of predictive analysis makes prognostic education important in the trade environment and commercial education programs (Makridakis, Wheelwright, & Hyndman, 2008). However, due to their difficulty, both statistics and predictive topics remain stressful subjects, even for students in the corresponding disciplines (Wathen & Rhew, 2019). Statistics education is no exception. Recently, several initiatives to raise people's awareness about its scientific and social aspects have arisen. However, there are no guidelines regarding the effective integration of forecasting in statistics education.

Since forecasting is an essential topic of management science that supports decision-making activities (Snider & Eliasson, 2013), it has been considered an important part of the economics and business curriculums (Gavirneni,

2008; Loomis & Cox Jr, 2003). Nevertheless, forecasting courses are not attractive to business schools' curriculums (Loomis & Cox Jr, 2003) or to students, probably due to their complexity (Albritton & McMullen, 2006). There is a lack of involvement of students' academic activities in management programs, which prevents them from realizing their full study potential. In current guidance, statistics development is generally seen as an element of administration or the business curriculum (Makridakis et al., 2008). Economic forecasting courses offer innovation and active study problems to update the course content and motivate students (Chu, 2007).

However, this study emphasized a didactic context and produced no empirical outcome related to learning. In addition, teaching manners and resources are suggested to upgrade instruction and training projections (Loomis & Cox Jr, 2003) to capture students' attention. Using network technology and practice based on true events to update lectures and teaching procedures are some of the educational guidelines that have been reported to have a positive effect on student motivation. In addition, virtual surroundings facilitate student participation in management courses (Gapp & Fisher, 2012). Finally, a prediction market was used as an educational instrument during business program lessons (Buckley, Garvey, & McGrath, 2011), creating true-to-life decision-making scenarios.

Students were interested in searching for additional material on the issue they were studying and were competent to use this acquired knowledge more deeply and adequately (Buckley et al., 2011). Therefore, using practical training and online science programs can make students more excited about learning statistics and prediction methods.

The peculiarities in the development of modern society and the importance of using statistics in the modern world require new approaches to the organization of the educational process and the development of new qualities in schoolchildren, who must be prepared and adapted to enter adulthood, where they will need to independently solve many issues, make forecasts, find optimal situations, and generate and offer ideas.

All this can be taught to students in the process of teaching prediction and analysis in math lessons. One of the steps taken to modernize the content of mathematics education was the inclusion of statistics in secondary school programs.

## 2. METHODOLOGY

The purpose of this study is to identify the needs of high school mathematics teachers in relation to the teaching of probability and statistics. In particular, it aims to determine:

1. The content knowledge of high school mathematics teachers.
2. The impact of the knowledge of mathematics teachers on students' performance.

### *2.1. Participants and Context*

A descriptive research method was employed for this study. The descriptive research design is intended to specify, define, or determine the level of content knowledge of high school math teachers in different Kazakhstani schools.

The survey respondents were 34 high school math teachers from more than 20 private and public schools in Kazakhstan. Data was collected from different types of schools, such as state schools, schools for gifted children, private schools, gymnasiums, physics and mathematics schools, and intellectual schools, to cover the state educational program, which was established by the Ministry of Education of the Republic of Kazakhstan. Although each of these schools has its own peculiarities in the structure and composition of curriculums, in Kazakhstan, the predominant educational institutions are state schools that adhere to the national educational standards. These schools cater to students from 1st grade to 11th grade and offer free education. Mathematics is a daily subject, incorporating statistical elements from secondary school onward. Specialized schools for gifted students, admitting 6th to 8th graders through entrance exams, follow a curriculum similar to public schools but emphasize natural sciences with increased weekly study hours. Gymnasiums provide comprehensive general and secondary education,

focusing on in-depth social subject training. Private schools in Kazakhstan are diverse in their approach and methodology, and they integrate foreign educational programs alongside the national curriculum. Intellectual schools, established in 2008, introduced the A-Level standard to the Kazakh program, emphasizing technical specialties in 22 schools nationwide. Admittance occurs through an entrance exam at the end of the 6th grade, with studies commencing in the 7th grade (Japashov, Naushabekov, Ongarbayev, Postiglione, & Balta, 2022).

It was necessary to obtain a strong understanding of the demands of all high school teachers in the area, so the total count method was utilized to choose the participants for this study. The study's goals were presented to each participant, and for ethical reasons, we secured the respondents' and school principals' informed consent. The respondents expressed confidence that their information would remain confidential. They were also made aware of the option to opt out of taking part in the study.

### *2.2. Data Collection*

A two-part survey was employed as the primary method of collecting information for this investigation. In the first section of the questionnaire, questions pertaining to gender, type of school, mathematics student performance (statistics), and the number of years the respondents had been teaching mathematics were posed. A detailed multiple choice test made up the second half, which consisted of 20 questions with four possible answers, where only one is correct. In accordance with language requirements, the participants were given a choice to complete the test in a language convenient for them. All the questions were directly from the field of mathematical statistics, the basics of which teachers of this subject should know.

The respondents' level of statistical and probabilistic expertise was assessed via a survey. This tool was revised with the help of experts. After the tool was proven to be valid and reliable by our experts (university teachers with a master's or PhD degree), various teachers were approached. The participants were given enough time to complete both the comprehensive test and the subject expertise questionnaire. Data collection was carried out through Google Forms, which included a questionnaire that was sent via links to the teachers. The teachers used their cell phones, personal computers, or tablets to answer the questions.

### *2.3. Data Analysis and Interpretation*

The data was examined by applying statistical analyses such as mean, proportion, standard deviation, percent right, and mean percentage scores. Most of the 34 respondents are aged between 21 and 40. In addition, female teachers accounted for 67% of the total respondents (see Figure 1). Most have a bachelor's degree; however, all of them are studying under specialized mathematical master's degree programs. As shown in Figure 2, almost half of the respondents have at least one year of work experience and a quarter have four or more years of experience. The types of schools where the interviewed teachers work are shown in the graph in Figure 3. The majority of the respondents work in public secondary schools (29.4%) and private schools (32.4%).

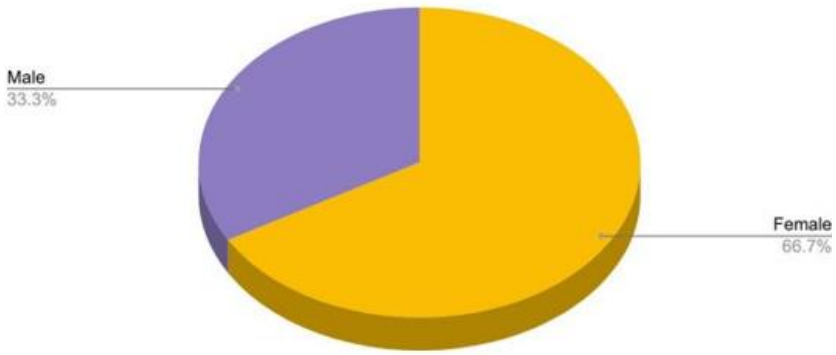


**Figure 1.** Gender.

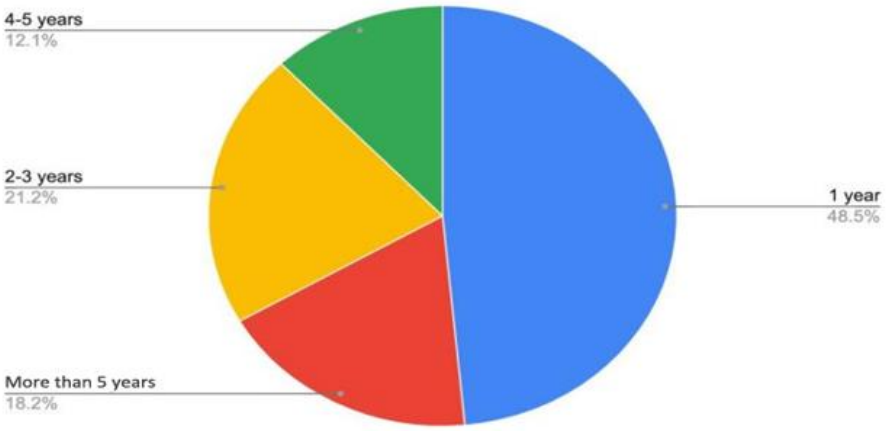


**Figure 2.** Work experience.

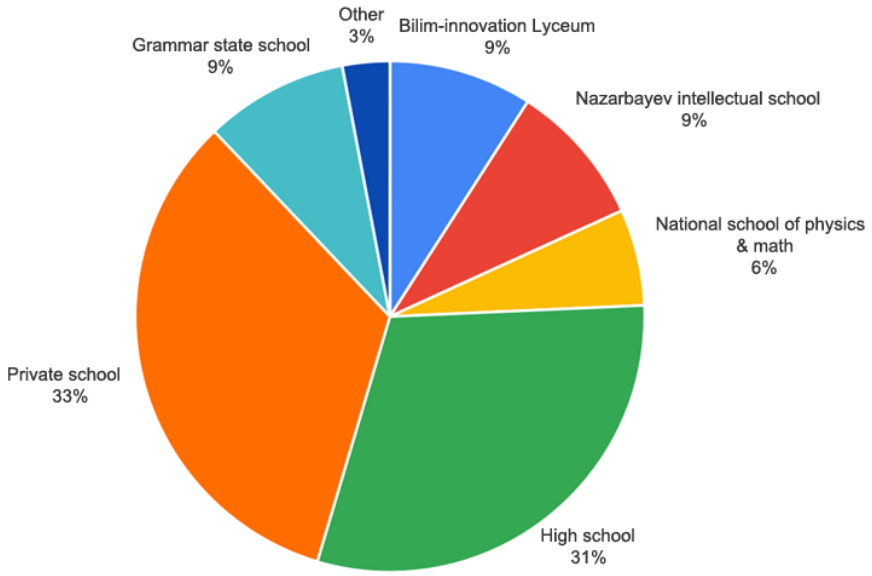


**Figure 3.** School type.

Most math teachers have a background in mathematics and are therefore unfamiliar or less familiar with statistical knowledge, reasoning, concepts, and methods. Consequently, when increasing the level of statistical training in secondary schools, more attention should be paid to appropriate training in content and pedagogy for teachers of statistics. Moreover, instead of focusing only on improving teachers' knowledge, teacher training and further professional development activities should also take into account teachers' attitudes, feelings or beliefs, and the influence of these factors on the teaching of statistics or the introduction of innovative educational technologies (Batanero, 2012). A correlation analysis of the data showed that we can be 52% sure that the better the teacher's level of knowledge in the field of statistics, the better the average score of students in mathematics lessons in the area of statistics. According to Batanero (2012), we should "pay attention to the statistical concepts and beliefs of mathematics teachers, since the thinking of mathematics teachers is a key factor in any approach to changing the teaching of mathematics and determines students' knowledge, and especially students' beliefs about mathematics."

Several authors have strongly emphasized the need for advanced training of mathematics teachers, as well as the need for constant support in teaching statistics so that they can prepare students to be statistically literate citizens (Batanero, Godino, & Roa, 2004; Jacobbe & Horton, 2012).

The regression analysis carried out in this paper can also help in forecasting the average score of students based on the teacher's result, and conversely, the equation and illustration of the regression can be observed (see Figure 4).

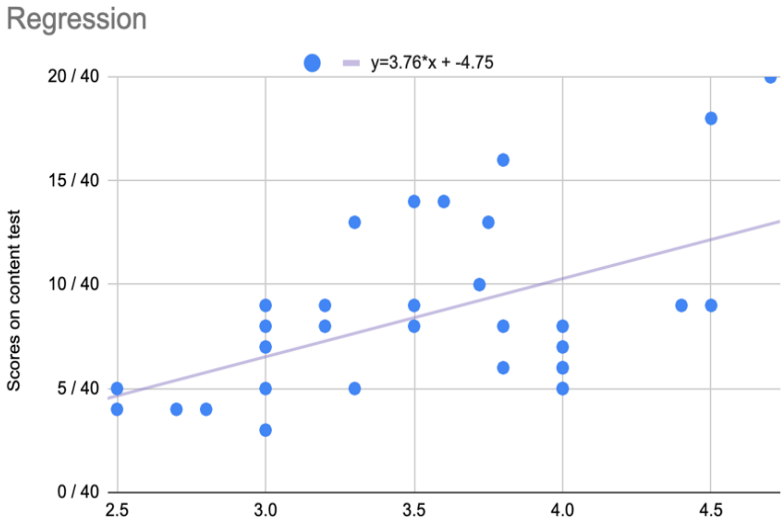


**Figure 4.** Regression analysis.

## 3. RESULTS

The results confirm the importance of teachers' knowledge of statistics and pedagogical content to determine the quality of their teaching and the relationship between the data and the performance of students in the classroom (Pfannkuch & Ben-Zvi, 2011).

The findings of the 20-item survey administered to the respondents show that they have a reasonable amount of topic knowledge on average (M = 8.97, SD = 4.191). Only three of the 33 respondents (9.09%) had a strong understanding of statistics, whereas 17 (51.51%) had a poor degree of knowledge on statistics, and nine (27.27%) had insufficient statistical content knowledge.

After conducting a normality check on the survey results obtained from the teachers, the Shapiro–Wilk test revealed a significant departure from normality [W(34) = 0.902, p = 0.005]. Given the sample size constraint ($n \leq 50$), the Shapiro–Wilk tables were utilized for p-value computation, with the normal distribution chart reserved for visualization due to the limited participant pool. The rejection of the null hypothesis was justified, as the p-value is $< \alpha$, where $\alpha = 0.05$, and indicates non-normal distribution. This implies a statistically significant difference between the data sample and a normal distribution. The p-value of 0.005332 [P(x≤2.5535) = 0.9947] suggests a minimal chance of type I error (0.53%), supporting H1 as the p-value decreases. The ensuing concerns about the data have potential implications for teachers' activities and development in statistical mathematics. The advent of a new mathematics curriculum and the enhanced integration of statistics necessitate a reconsideration of teachers' professional identity, task perception, and motivation. This prompts reflection on the sources of job satisfaction and the working conditions deemed essential for effective teaching. Consequently, this study underscores the limited emphasis on statistical education for mathematics teachers in secondary schools and advocates for the development of contextualized processes for interpreting statistics in mathematics education.

## 4. CONCLUSION

The majority of high school math teachers are women with a bachelor's degree, but they are also students for the acquisition of a master's degree, and they are relatively new to the teaching profession. It was revealed that the respondents' knowledge of the statistics program was below the required skill level. For math educators, teaching statistics and probability is not a simple task. They need to increase their subject knowledge and teaching abilities to deliver lessons with ease and ensure that their students comprehend the subject's ideas, material, and implementations.

As part of the upper secondary school curriculum, teachers need to be competent in the subject to help their students. It is advised that teacher training be frequently carried out through the training and advanced internship

departments in light of the findings of this study. This education should focus primarily on the content as well as on the methodology and studies used by high school seniors' probability and statistics teachers. These workshops can assist high school instructors in developing their pedagogical and statistical topic expertise, particularly in terms of making mathematics teaching and learning entertaining, inventive, and better adapted to the characters and learning styles of their students. In addition, research abilities can benefit teachers in recognizing the personalities of their students, developing and identifying approaches to enhance their own learning, and improving the academic achievement of their pupils. The findings of this study indicate that instructors require the assistance of other organizations, particularly regarding resources, infrastructure, and psychological and social needs. The results of this analysis reflect those of Anthony and Walshaw (2009), who found that, while teachers can be imaginative and inventive, they can acquire knowledge by collaborating with a group of encouraging fellow mathematicians. Initiatives for career progression are commonly the motivation for significant improvements.

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**Transparency:** The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
**Competing Interests:** The authors declare that they have no competing interests.
**Authors' Contributions:** All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

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